Liquid crystal micro-cells for tunable VCSELs

Olivier Castany, Laurent Dupont, Cyril Paranthoen, Christophe Levallois, Alain Le Corre, Slimane Loualiche

Liquid crystal micro-cells for tunable VCSELs

Olivier Castany, Laurent Dupont
Optics Department, Telecom Bretagne, UMR CNRS 6082, 29238 Brest, France
C. Paranthoen, C. Levallois, A. Le Corre, S. Loualiche
FOTON-INSA, UMR CNRS 6082, 35043 Rennes, France
e-mail: olivier.castany@telecom-bretagne.eu

Topic : Integration of technologies

***Abstract*—We recently demonstrated the tunability of a VCSEL with an intra-cavity liquid crystal layer. This demonstration was made on a macroscopic-sized sample with optical pumping. For a further development of this solution, it is necessary to place the liquid crystal on microscopic VCSEL chips. We developed a microtechnology process which makes it possible to fabricate liquid crystal micro-cells in a collective process.**

I. Tunable VCSEL with intra-cavity liquid crystal layer

We recently demonstrated a new type of tunable VCSEL laser. This device has no moving part as opposed to MEMS tunable VCSELs and tunability is achieved with an intra-cavity liquid crystal layer.

The switching of the liquid crystal varies the optical length of the cavity seen by the extraordinary mode. As a consequence, the emission wavelength of the extraordinary mode varies as a function of the voltage applied to the liquid crystal. At the same time, if the ordinary modes are located in spectral regions with lower gain, they do not participate to the laser emission. In this situation, the emission has a single mode, with a polarization along the extraordinary direction.

The sample is made of the following parts: the bottom mirror is a a-Si/a-SiN_x Bragg mirror, the active region features nine quantum wells grown on InP and the top mirror is a SiO_2/TiO_2 Bragg mirror. The liquid crystal layer is a few microns thick, between the active region and the top mirror. We used a nematic liquid crystal with a planar alignment. The laser is optically pumped at 1.06 µm and the output spectra are presented on figure 1 as a function of the voltage applied to the liquid crystal.

The result demonstrates a tunability of a least 40 nm around 1550 nm, with a few volts of applied voltage, and polarization control due to mode selection.

This demonstration was made on a sample with a size of a few millimeters. However, for a further development of the project, it will be necessary to place the liquid crystal on microscopic laser chips.

II. Liquid crystal micro-cells

The use of liquid crystals in miniature opto-electronic devices has often been hampered by the difficulty to miniaturize the liquid crystal cells. A goal of this work is to build individual liquid crystal cells, including alignment films and driving electrodes, with dimensions smaller than a millimeter. The process which we developed allows the collective fabrication of several micro-cells at the same time. It is possible to place these micro-cells on an array of hybridized VCSEL chips.

For that purpose, we developed the collective process pictured on figure 2 [1]. Pillars are prepared on the bottom substrate and caps are deposited on the pillars by a transfer method from a top substrate. The caps feature a via for electrical connection to the driving electrode. The pillars and the caps are fabricated by photolithography in SU-8 photoresist. The liquid crystal alignment layers are prepared with a photo-alignment technique. The bond between the caps and the pillars is made with a polymerizable liquid crystal material which acts at the same time as a glue and as an alignment surface for the liquid crystal. The transfer of the caps form the top substrate is possible because the top substrate was prepared with a release coating. The top electrode is made with a PEDOT:PSS conducting polymer. Finally, a nematic liquid crystal is filled into the micro-cell.

The resulting micro-cells have a well controlled geometry and the surfaces have an optical quality. The liquid crystal is well aligned. When voltage is applied on a via, the switching behavior is observed (see figure 3). It is the same behavior as with a macroscopic liquid crystal cell.

Low cost production of VCSELs is achieved by hybridizing the chips on a silicon bench. It is possible to deposit micro-cells on an array of hybridized components. However, the tops of the hybridized components do not have exactly the same height and it is necessary to accommodate with these variations. A reliable process uses a soft stamp as a top substrate, which can accommodate with height and horizontality variations. Figure 4 shows a micro-cell built on a hybridized component.

III. Conclusion

We demonstrated the tunability of a VCSEL with an intra-cavity liquid crystal layer and we developed a collective process which makes it possible to place liquid-crystal micro-cells on hybridized chips.

The main application of tunable VCSELs is for optical transmission on a WDM network. Other applications are gas sensors and optical fiber Bragg grating sensors. Liquid crystal micro-cells are an element for the fabrication of liquid crystal tunable VCSELs. Other applications are the tuning of microwave circuits and liquid crystal micro-lenses.

Reference

[1] O. Castany and L. Dupont. Eason, “Liquid crystal micro-cells: collective fabrication of individual micro-cells,” Journal of Micromechanics and Microengineering, vol. 20(6), p. 065019, 2010.

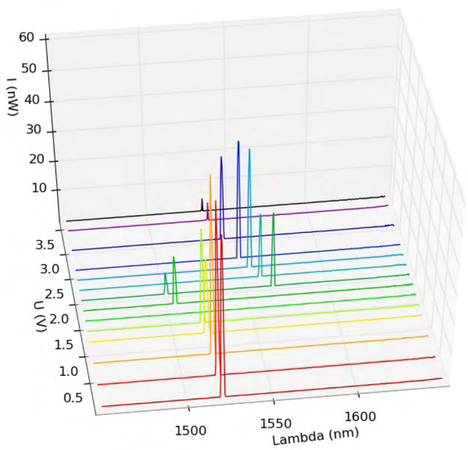

Figure 1. Laser emission spectrum as a function of the voltage applied to the liquid crystal.

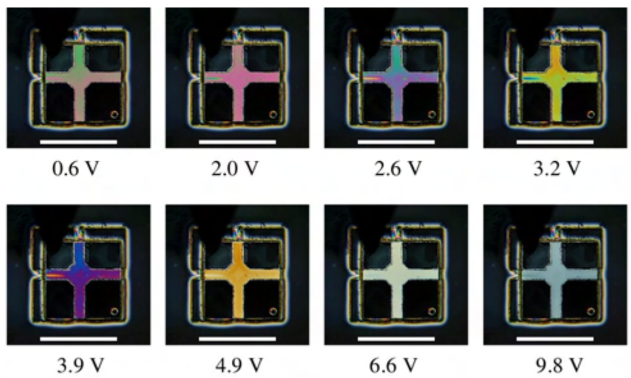

Figure 3. Successive images of a micro-cell observed between crossed polarizers (45° away from the horizontal) with increasing voltage. The white bar is 500 µm long. Exposure time of the camera is kept constant.

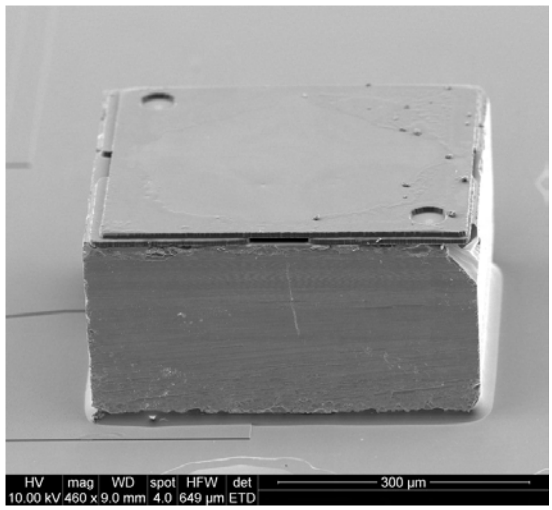

Figure 4. Micro-cell fabricated on a hybridized chip.

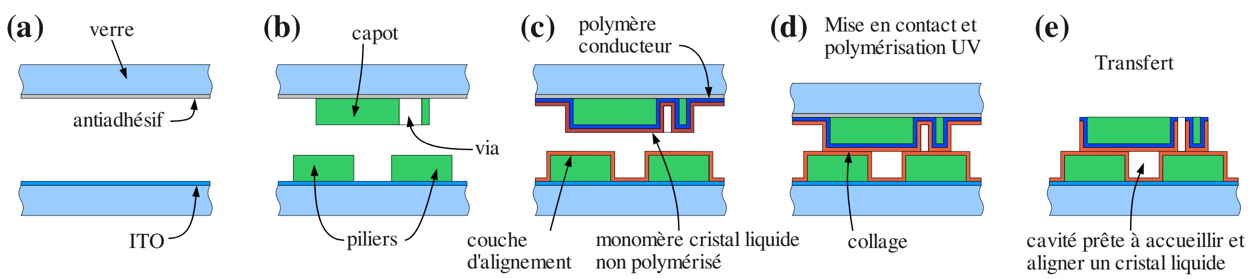

Figure 2. Fabrication process of the micro-cells.